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Web Cartography Tool for Road Safety | Pedestrian crossings in focus

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Summary

It is sad to hear that, in Switzerland the number of fatally injured pedestrians increased by 35% in 2015 and paradoxical, that one third of these victims was killed on pedestrian crossings. In the city of Zurich there is a rise in the accidents involving pedestrians, bicyclists and e-bikers, while injuries and even fatalities have been recorded on pedestrian crossings. Sensibilised by the aforementioned road safety issues and within the spirit of relevant campaigns run by the Swiss Federal Roads Office and the city of Zurich, the objective of the present interdisciplinary project is to examine the aptness of the existing pedestrian crossings in district 1 of the city of Zurich. The assessment is based on the comparison of the geometric design, the surroundings and the traffic conditions at the pedestrian crossings with a standard that is considered as the ideal pedestrian crossing. The main definition of such a standard is given in the Swiss Norm 640241. Within the framework of this study, a toolbox has been developed for the implementation of the rules described in the norm. Additionally, a website was created, as well as a web map application where the results of the project are presented. The final product could probably serve as an assisting tool for road authorities and perhaps as information medium for the general public.

Key Words: pedestrian crossings, road safety, blackspots, road accidents, Zurich, District 1, swiss norm, SN640241, web cartography, Web AppBuilder for ArcGIS (Developer Edition), ArcPy

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Abbreviations

3D	Three-Dimensional
AADT	Annual Average Daily Traffic
DAV	Department of Transport
FEDRO	Swiss Federal Roads Office
IVT	Institute for Transport Planning and Systems
km/h	kilometers per hour
m	meters
SN	Swiss Norm
SNR	Swiss Rule
VRU	Vulnerable Road Users

1 Introduction

Over 1.2 million people pass away each year on the world's roads [1], a number that corresponds to one human loss every 30 seconds [2]. More than one fifth of these deaths are recorded to occur among pedestrians and perhaps the actual proportion is even higher, taking into consideration that in many countries, crashes involving pedestrians are poorly reported in official road traffic injury statistics. Globally, among the deceased, 5% are cyclists [3]. Talking about the EU countries, pedestrian and cyclist fatalities represent 17% and 6% respectively of the total traffic fatalities [4]. As far as Switzerland is concerned, comparing 2015 with 2014, the number of pedestrian fatalities increased by 35%. As for cyclist fatalities, there is a drop of 14%, which is unfortunately undermined by a soar of 180% in e-biker fatalities [5]. Regarding Zurich, a rise in the accidents involving pedestrians, bicyclists and e-bikers is observed [6]. It is noteworthy that out of the six people that were killed in Zurich's roads in 2015, four of them were pedestrians, and there were a cyclist and a public transport user as well [6].
According to the European Commission, crashes involving pedestrians and cyclists occur frequently at facilities designed exclusively for them such as pedestrian crossings, cycle tracks and cycle lanes [4]. In Switzerland, one third of the pedestrian victims of 2015, were killed on pedestrian crossings [5] and in the city of Zurich records about injuries and even fatalities of such, unprotected road users, on pedestrian crossings exist [7] and are still being recorded (*Figure 1.1*).

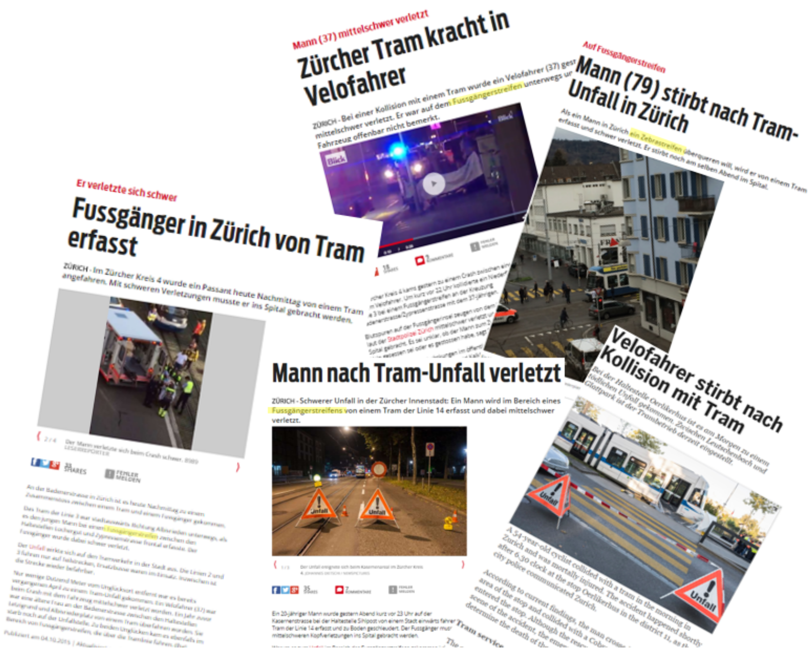


Figure 1.1: Recent press publications about accidents involving vulnerable road users, that occurred on pedestrian crossings [8], [9], [10], [11], [12]

The last-mentioned fact is sad and oxymoron, and apparently, it needs immediate attention. Apart from the general road safety strategy of the Federation, entitled *Via Sicura*, which aims at the reduction of fatalities and injuries on Swiss roads [13], the city of Zurich runs the *Zebra Safari* project, in the framework of which they are at the moment collecting data, in order to assess the existing pedestrian crossings. The results are expected to be announced by mid 2017 [14].
Sensibilised by these road safety issues and within the spirit of the aforementioned campaigns run by the Federation and the city of Zurich, the objective of the present interdisciplinary project is to examine the aptness of the existing pedestrian crossings in District 1 of the city of Zurich and consequently to contribute towards the safety of vulnerable road users (VRU).
To this end, a toolbox has been developed for the detection of insufficient pedestrian crossings, accompanied by a web map application, as well as a website, for the presentation of results and the communication

to the public.
More details are given in the main body of the report, which is structured as follows:
Chapter 2 includes a short history of pedestrian crossings, focused on Switzerland, along with information about the legal framework and relevant definitions.
Chapter 3 presents the features of pedestrian crossings, as described in the Swiss Norm of 2000 and the reviewed one of 2016 and how these differ from each other.
Chapter 4 is an attempt to highlight the characteristics of road accidents involving pedestrians, which occur at pedestrian crossings, by examining their statistics and spatial distribution.
Chapter 5 treats the assessment of pedestrian crossings. The appraisal method and its implementation are presented in detail, followed by the results of the assessment.
Chapter 6 is dedicated to the web map application that was developed to showcase the results of the present study while
Chapter 7 refers to the website that was created to serve as information medium for the general public.
Finally, in *Chapter 8* conclusions are drawn and future steps are announced.

2 Pedestrian Crossings in Switzerland - A General Overview

This chapter is all about general facts on pedestrian crossings, focused on Switzerland. First of all, a brief history of pedestrian crossings is provided. Then, the legal framework is presented and finally relevant definitions are given.

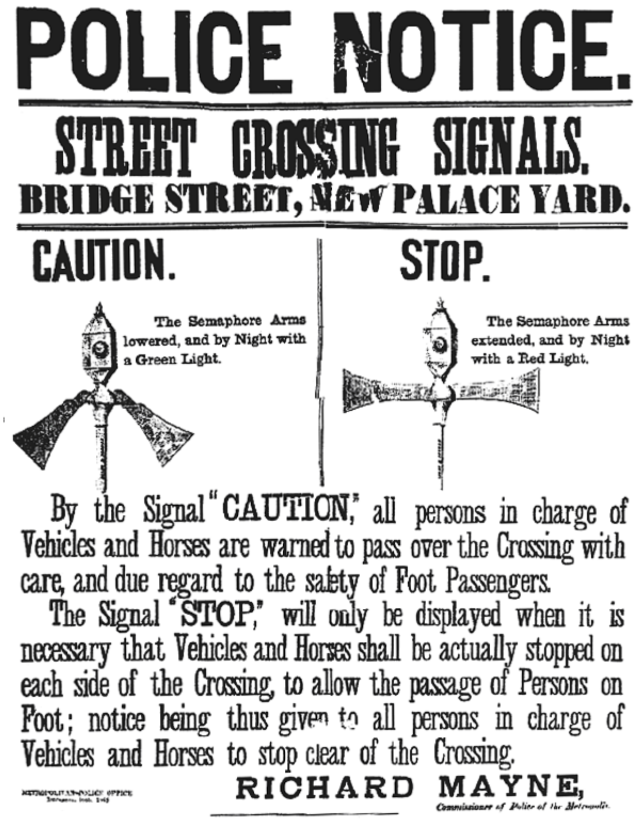
2.1 History of Pedestrian Crossings

Some sort of pedestrian crossings appeared in Roman antiquity [15]. At that time, crosswalks were envisaged as stepping stones that could protect the upper-class residents of Pompeii (*Figure 2.1*) from road-level dirt [16]. Therefore, pedestrian crossings consisted of stone-blocks, raised up to the level of the tall sidewalks (1.5 feet high) [15]. These 3D stripes were designed so as to ensure the ease to step on, allowing the circulation of horse-drawn carts and considering the drainage and sewage system [17].

Figure 2.1: Pedestrian crossing in Pompeii [18]

No records about crosswalks exist in the Middle Ages [15]. Footpaths appeared in London of the seventeenth century, having hygiene and drainage as primary motivation for their development [19] and Paris's streets were flanked by sidewalks in the eighteenth century [15]. However, until then there were no measures for street crossing by pedestrians. It was in 1868, that the first experimental traffic signal giving priority to foot passengers was established in London (*Figure 2.2*). Unfortunately, this idea was later neglected, for it didn't improve pedestrian safety. Suggestions were made for subway tunnels and footbridges, but the cost and the natural tendency of pedestrians to prefer the shortest path were deterrent. Road marking experimentation began in the 1930's and pedestrian crossings were eventually established in Britain [19].

In Switzerland, crosswalks are first recognised in the legislation in 1932. Later, the pedestrian priority on pedestrian crossings was legislated. In the early 1960's the rights as well as the obligations of pedestrians were defined. Since 2000, the design of pedestrian crossings is also standardised.


POLICE NOTICE.

STREET CROSSING SIGNALS.

BRIDGE STREET, NEW PALACE YARD.

CAUTION. | STOP.

The Semaphore Arms lowered, and by Night with a Green Light.

The Semaphore Arms extended, and by Night with a Red Light.

By the Signal "CAUTION," all persons in charge of Vehicles and Horses are warned to pass over the Crossing with care, and due regard to the safety of Foot Passengers.

The Signal "STOP," will only be displayed when it is necessary that Vehicles and Horses shall be actually stopped on each side of the Crossing, to allow the passage of Persons on Foot; notice being thus given to all persons in charge of Vehicles and Horses to stop clear of the Crossing.

RICHARD MAYNE,

Figure 2.2: Police notice for the first traffic signal giving priority to pedestrians in London [17]

As far as their appearance is concerned, in the beginning they were marked with studs on the pavement. Afterwards the yellow-line marking was recommended and both ways of marking were mentioned in the legislation [15]. Since 1961, the crosswalks in Switzerland are marked with yellow longitudinal stripes [20].

Figure 2.3: Left: Pedestrian crossing | Zurich, 1963 [21]
Right: Pedestrian crossing | Zurich, n.d. [22]

What is more interesting to note here is that the use of pedestrian crossings today has nothing to do with that in the Roman antiquity. More specifically, pedestrian crossings are now used to concentrate pedestrian traffic, to give priority to pedestrians and to protect them from motorised traffic.

2.2 Legal Framework

The 35th article of the *Federal Law for Motorised Vehicles and Bicycles*, issued in 1932, recognised for the first time areas reserved for pedestrians to cross the road. Later, the 45th article of the *Executive Ordinance to the Act* defined pedestrian priority as follows: "When approaching pedestrian crossings, drivers should slow down or stop to let all pedestrians being on the pavement to cross". The *Federal Law for Road Traffic* was adopted in 1958 and came into effect with the *Ordinance to the Rules of Road Traffic* in 1963, defining the rights and the obligations of pedestrians [15]. Afterwards, the pedestrian crossings were standardised with Swiss Norms. The respective standard is the SN 640241, issued in 2000 and revised in 2016.

2.3 Relevant Definitions

Detection Distance

Detection distance is the distance at which a driver detects either the longitudinal marking or the 4.11 sign and consequently, the pedestrian crossing [23].

Pedestrian

A pedestrian is any person who is travelling by walking, running, jogging or hiking for at least part of their journey. Even people sitting or laying down in the roadway are considered as pedestrians. A pedestrian might use aids to walking such as wheelchairs, motorised scooters, walkers, canes, skateboards and roller blades [3].

Pedestrian Crossing

A pedestrian crossing or crosswalk, is a point on the road where pedestrians traverse the road. It may be found at intersections or along road stretches and it can be a marked or a signalised crossing [3]. Concerning Switzerland, pedestrians have priority over motorised traffic on pedestrian crossings, except for vehicles on rails, provided that there is no signal control or manual control by an authorised person [23].

Unprotected Users

Pedestrians and cyclists are often characterised as unprotected. Indeed, they are relatively unprotected, as they cannot protect themselves against traffic, which may have high speed and big mass and therefore, they suffer the most severe consequences in the unfortunate case of a collision [3].

Visibility Distance

Visibility distance is the distance at which mutual eye-contact between driver and pedestrian is guaranteed. The visibility distance refers to the road segment of free vision, including the waiting rooms on both sides of the road (see also *Figure 3.2*) [23].

Vulnerable Road Users (VRU)

VRU are the non-motorised road users, including pedestrians, cyclists, motor-cyclists, as well as persons with disabilities or reduced mobility and orientation [24].

Waiting Room

Waiting room is the physically separated from the pavement zone, which leads to the pedestrian crossing and is reserved for pedestrians [23].

3 Standards of Pedestrian Crossings

Many countries have developed their own standards for the design of pedestrian crossings, so has done Switzerland. The Association of Swiss Road and Traffic Engineers, issued the respective Swiss Norm in 2000. The SN 640241, as it is called, was revised in 2016. It was probably the statistics about pedestrians killed on pedestrian crossings that raised the concern and led to this review.

3.1 Swiss Norm 640241 (2000)

The SN 640241, issued in 2000, applies to all pedestrian crossings, existing or planned for public streets. According to this norm the design of pedestrian crossings should obey the following rules (main rules selection) [25]:

Equipment

Lighting: Luminance of at least 2cd/m^2 should be ensured.

Road Signs: A 4.11 sign should always be placed at pedestrian crossings (*Figure 3.3*).

Geometry

Waiting room on sidewalk: A length of 4.00m is recommended and a minimum of 3.00m should always be respected. A depth of at least 1.20m should be respected.

Waiting room on refuge island: A width of 2.00m is recommended and a minimum of 1.50m should always be respected.

Location

Location with respect to bus stop: In general, pedestrian crossings should be placed before bus stops. However, they might exceptionally be placed after the bus stop. In any case, measures should be taken to prevent bus overtaking, such as refuge islands and continuous security lines.

Location with respect to tram stop: Refuge islands should be placed before and after the tram stop.

Location with respect to intersection: The pedestrian crossings of the priority road should be placed as close to the intersection as possible, whereas the pedestrian crossings of the non-priority road should be placed at least 5m back to ensure visibility (2m in case of signalised crossings).

Traffic Conditions

Speed: If the speed is higher than 50km/h, complementary measures or other different measures should be taken.

Number of pedestrians and traffic volume: In general, a pedestrian crossing should be placed when the crossing is used by at least 100pedestrians during the three to five busiest hours of the day. When the demand is lower but the crossing serves a specific group of pedestrians, such as schoolchildren, a pedestrian crossing may exceptionally be placed. *Figure 3.1* shows the fitness of a pedestrian crossing based on the vehicular and pedestrian traffic.

Visibility

In general, a visibility distance of 100m should be ensured. In any case this distance should not be smaller than indicated in the table below (*Table 3.1*):

Table 3.1: Minimum visibility distance based on the speed (2000) [25]

Speed Limit or V_{85} (km/h)	Minimum Visibility Distance (m)
40	40
50	55
60	70

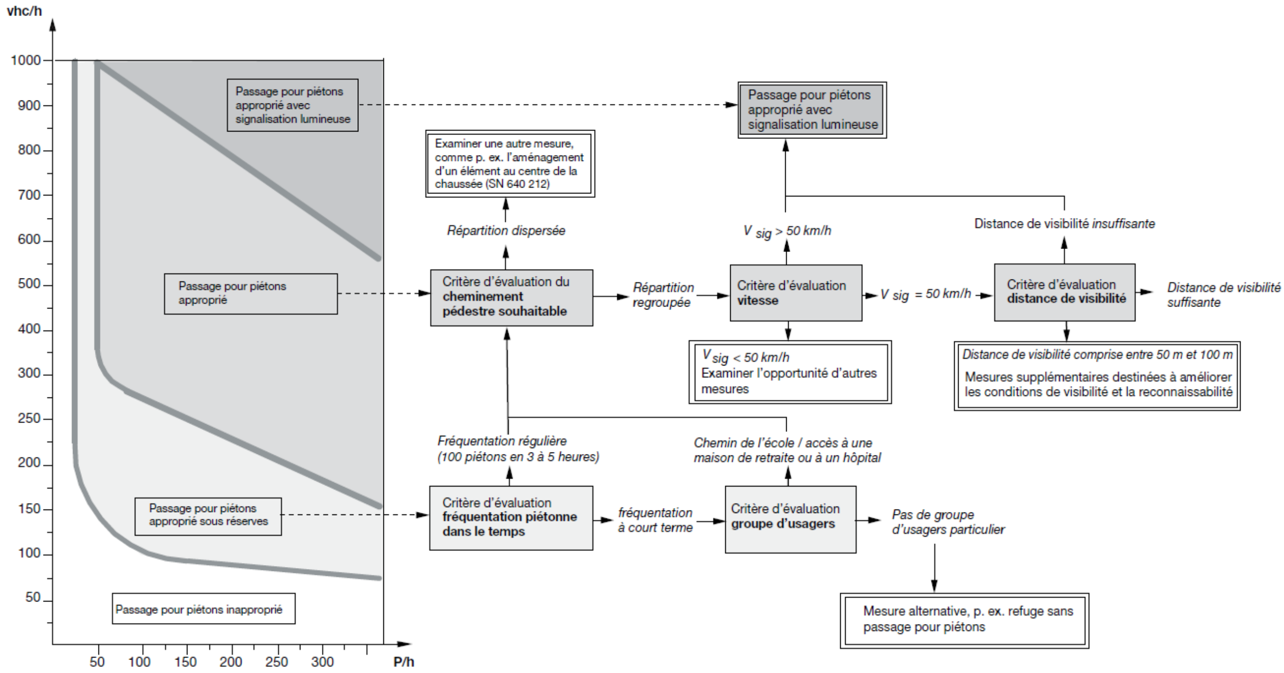


Figure 3.1: Fitness of a pedestrian crossing considering the vehicular and pedestrian traffic [25]

3.2 Swiss Norm 640241 (2016)

The SN 640241 was reviewed in 2016. The new norm refers to non-signal controlled pedestrian crossings [23], probably assuming that the traffic lights ensure the required safety for pedestrians on signalised crossings. The main rules of the revised norm are listed below [23]:

Equipment

Lighting: Illuminance of at least 5LUX should be ensured. Moreover, the distance between the light post and the middle of the waiting room at the sidewalk should be such that the following equation is respected (see also *Figure 3.2*) [26]:

x = 0.5 - 1.0 LPH

where

x: the distance between the light post and the middle of the waiting room
LPH: the height of the light post

Road Signs: A 4.11 sign should always be placed at pedestrian crossings, except for the case of non-priority streets. In suburban areas, whenever the detection distance criterion is not fulfilled a 1.22 (*Figure 3.3*) should also be placed, usually accompanied by a panel indicating the distance to the pedestrian crossing. It noted that the visibility distance criterion though should always be fulfilled.

Geometry

Waiting room on sidewalk: A length of 4.00m is recommended and a minimum of 3.00m should always be respected. A depth of at least 1.50m should be respected.

Waiting room on refuge island:	A width of 2.00m is recommended and a minimum of 1.50m should always be respected.
Number of Refuge islands:	Refuge islands should always be placed on bidirectional roads with one lane per direction, when the width is higher than 8.50m. Refuge islands should also be planned between lanes of the same direction at priority roads, no matter the width of the road, the traffic volume and the existence of public transport dedicated lanes.

Location

Location with respect to bus stop:	In general, pedestrian crossings should be placed before bus stops. However, they might exceptionally be placed after the bus stop. In any case, measures should be taken to prevent bus overtaking, such as refuge islands and continuous security lines.
Location with respect to tram stop:	Refuge islands should be placed before and after the tram stop.
Location with respect to intersection:	The pedestrian crossings of the priority road should be placed as close to the intersection as possible, whereas the pedestrian crossings of the non-priority road should be placed at least 5m back to ensure visibility.
Location with respect to other pedestrian crossings:	The minimum distance between two consecutive pedestrian crossings is 50m, if there are not any public transport stops around.
Location with respect to traffic lights:	The minimum distance between a marked pedestrian crossing and a traffic light is 125m, if the crossing is not close to a signalised intersection.

Traffic Conditions

Speed:	Both the speed limit and the effective speed should not exceed 60km/h at pedestrian crossings.
Number of pedestrians:	A pedestrian crossing should be placed when the crossing is used by at least 100pedestrians during the five busiest hours of the day. When the demand is lower but the crossing serves a specific group of pedestrians, such as schoolchildren, a pedestrian crossing may exceptionally be placed.
Traffic volume:	A pedestrian crossing is necessary when the annual average daily traffic (AADT) is higher than 3000vehicles.

Visibility

The visibility distance should not be smaller than shown in the table below:

Table 3.2: Minimum visibility distance based on the speed (2016) [23]

Speed Limit or V_{85} (km/h)	Minimum Visibility Distance (m)
30	25
40	40
50	55
60 (urban area)	75
60 (suburban area)	100

Since the speed is inextricably linked to the radius of the curve, the following table presents the respective minimum visibility distances for pedestrian crossings placed after curves (*Table 3.3*).

Table 3.3: Minimum visibility distance based on radius of the curve (2016) [23]

Radius of the curve in the middle of the lane (m)	Minimum Visibility Distance (m)
20	30
25	35
30	40
35	45
40	50

For the placement of a pedestrian crossing at the end of a curve, the following criteria should also be satisfied:

- There should be at most one lane per direction.
- The general speed limit should be 50km/h.
- There longitudinal slope should not exceed 5%.
- At least 60° of the curve should be travelled until the vehicle reaches the pedestrian crossing.

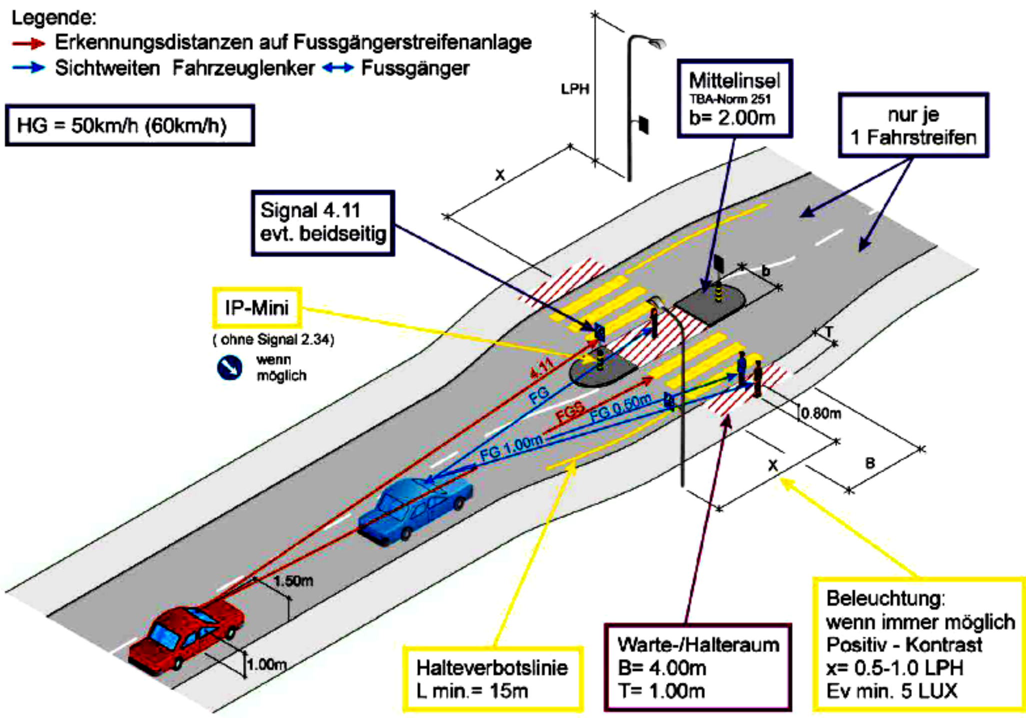


Figure 3.2: The standard as described in 2014 [26]

Figure 3.3: Left: Sign 4.11 | Location of pedestrian crossing [27]
Right: Sign 1.22 | Pedestrian crossing [27]

3.3 Differences Between the Norms

Generally, apart from the fact that the norm of 2000 refers to all pedestrian crossings while the new one applies only to non-signalised crossings, the new norm seems to be more specific, as well as more strict in terms of values.

4 Accidents on Pedestrian Crossings - Focus on District 1, Zurich

As mentioned in the introductory section, crashes involving pedestrians occur frequently on pedestrian crossings. This chapter is an attempt to reveal characteristics of pedestrian road accidents which occur at pedestrian crossings. The analysis is based on the statistics and the spatial distribution of such accidents, as well as on the comparison with the features of other pedestrian road accidents.

4.1 Statistics

Statistics can reveal patterns and trends and this is the aim of the present section, to examine the statistics related to crashes on pedestrian crossings involving pedestrians and hopefully reveal details that could contribute to the prevention of such crashes.

4.1.1 General characteristics

As far as the first district of Zurich is concerned, 28% of the road accidents that happened between 2013 and 2015 involved pedestrians and half of these accidents occurred on pedestrian crossings (*Table 4.1*).

Table 4.1: Road Accident Statistics for District 1, Zurich (2013-2015) | Data Source: FEDRO, 2016

Total Road Accidents	Accidents Involving Pedestrians
388	110 (28%)

Pedestrian Accidents on Pedestrian Crossings	Other Pedestrian Accidents
56 (51%)	54 (49%)

More than three quarters of the pedestrian accidents were slight, while around one quarter of them was severe (*Figure 4.1*). There was only one fatal accident, which did not occur on pedestrian facilities. It is note-worthy that the area of this accident is a blackspot, where other road accidents have also happened, some of which involved pedestrians (*Figure 4.9*).

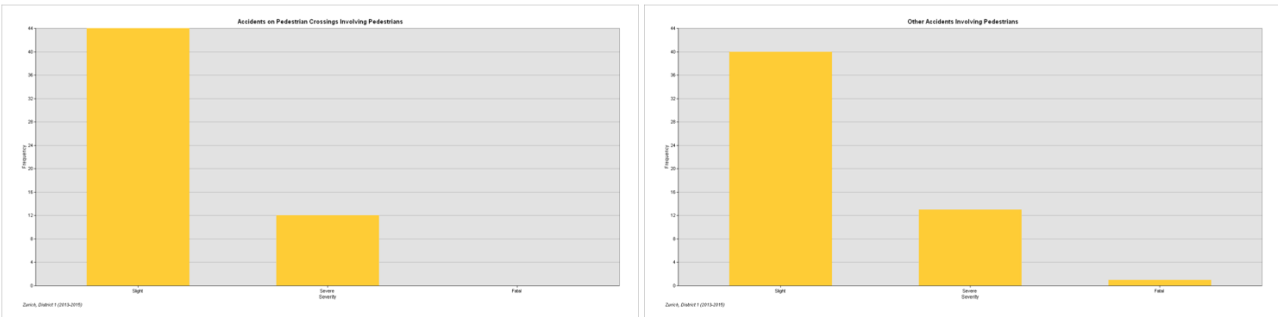


Figure 4.1: Left: Pedestrian accidents at pedestrian crossings - Severity
Right: Pedestrian accidents at other areas of the road network - Severity
Data source: FEDRO, 2016

The majority of the pedestrian accidents happened on secondary streets (*Figure 4.2*). A quarter of the accidents that involved pedestrians happened at night (*Figure 4.3*), and one out of three of such accidents resulted in severe injuries (*Figure 4.4*). The respective proportion during the day was one out of five (*Figure 4.5*).

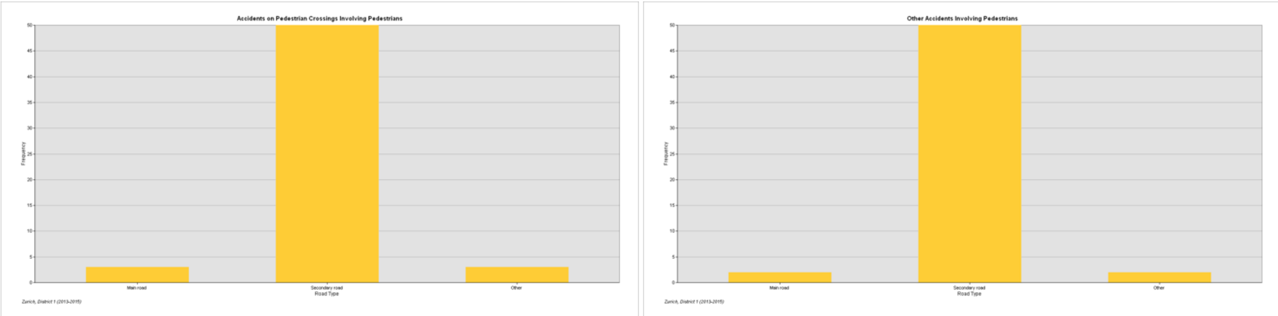


Figure 4.2: Left: Pedestrian accidents at pedestrian crossings - Road type
Right: Pedestrian accidents at other areas of the road network - Road type
Data source: FEDRO, 2016

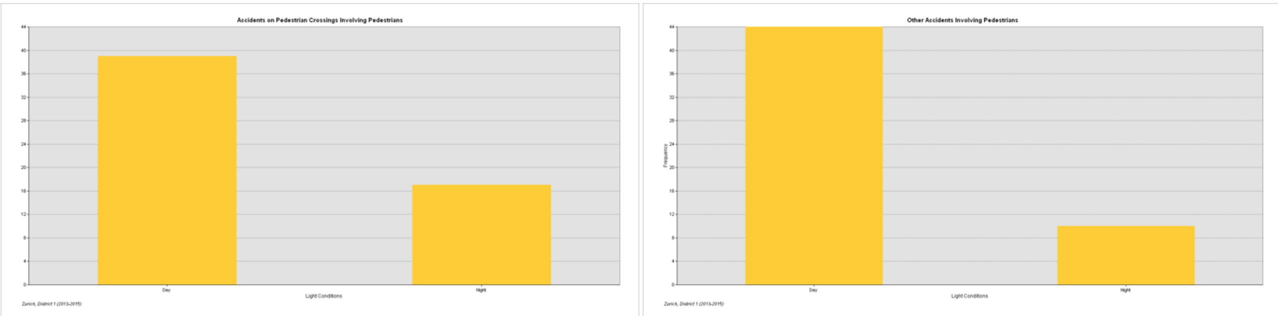


Figure 4.3: Left: Pedestrian accidents at pedestrian crossings - Light conditions
Right: Pedestrian accidents at other areas of the road network - Light conditions
Data source: FEDRO, 2016

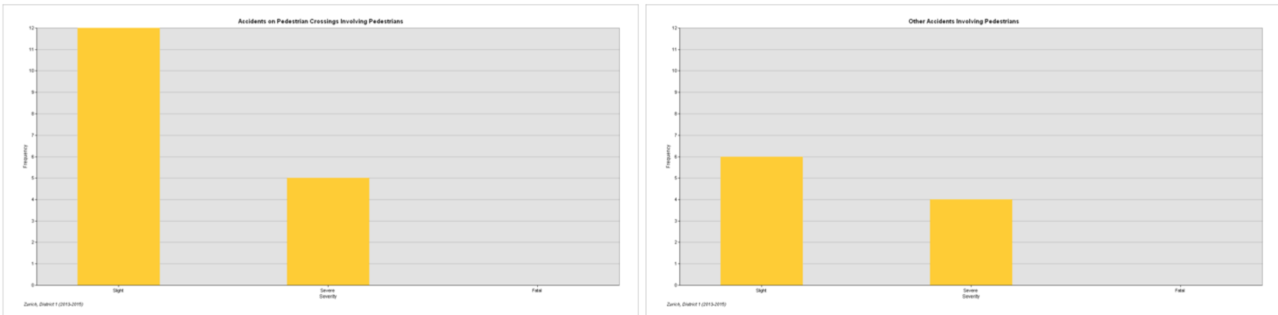


Figure 4.4: Left: Night pedestrian accidents at pedestrian crossings - Severity
Right: Night pedestrian accidents at other areas of the road network - Severity
Data source: FEDRO, 2016

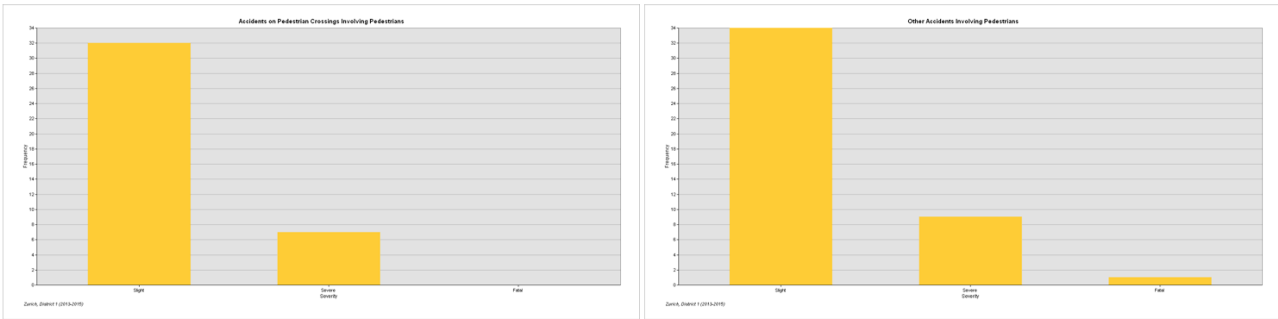


Figure 4.5: Left: Day pedestrian accidents at pedestrian crossings - Severity
Right: Day pedestrian accidents at other areas of the road network - Severity
Data source: FEDRO, 2016

4.1.2 Temporal patterns

Trying to identify potential temporal patterns, the following graphs were produced, comparing pedestrian accidents that occurred at pedestrian crossings with pedestrian accidents that happened at other areas of the road network (*Figure 4.6, Figure 4.7, Figure 4.8*). What is interesting to note is that the day distribution of pedestrian accidents at pedestrian crossings follows a pattern that reminds of the traffic volume pattern, it is characterised by a regularity probably connected with scheduled trips and perhaps related to regular road users, a pattern which is not answered in pedestrian accidents that occurred at other areas of the road network. A similar regularity is also noticed in the time distribution of pedestrian accidents at pedestrian crossings. More specifically, such accidents are observed mostly between 06:00 and 00:00, which are the high activity hours for modern humans. In the contrary, there isn't a pattern like this in the pedestrian accidents that occurred at other areas of the road network. Thus, it seems that the pedestrian accidents which happen at pedestrian crossings and the pedestrian accidents which occur at other parts of the road network constitute two separate accident categories.

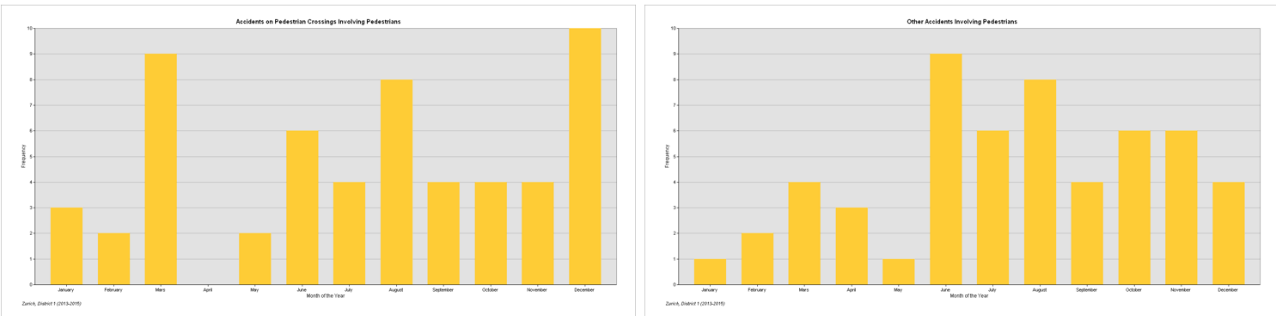


Figure 4.6: Left: Pedestrian accidents at pedestrian crossings - Month distribution
Right: Pedestrian accidents at other areas of the road network - Month distribution
Data source: FEDRO, 2016

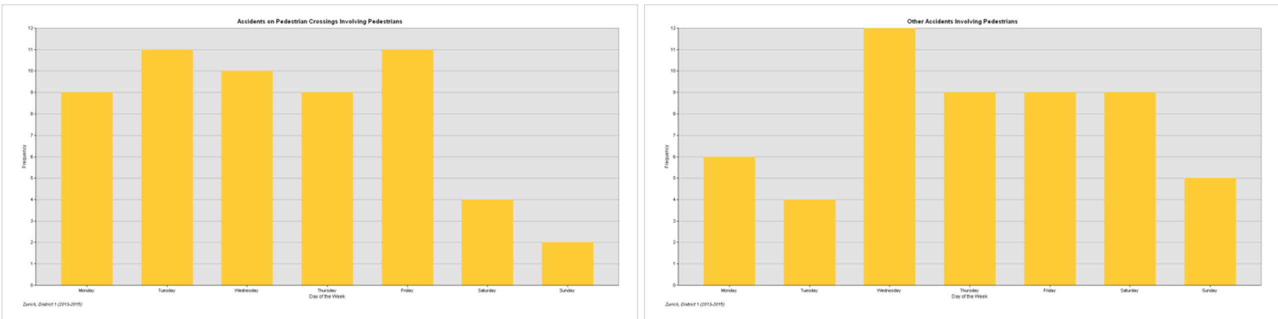


Figure 4.7: Left: Pedestrian accidents at pedestrian crossings - Day distribution
Right: Pedestrian accidents at other areas of the road network - Day distribution
Data source: FEDRO, 2016

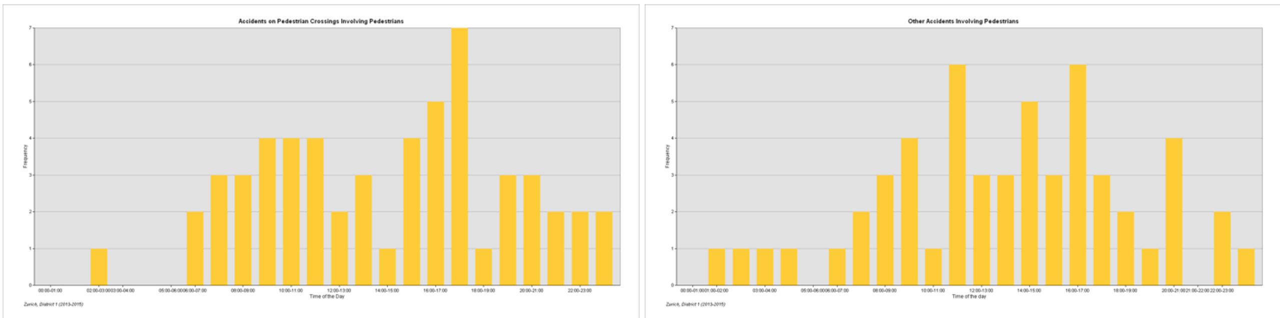


Figure 4.8: Left: Pedestrian accidents at pedestrian crossings - Time of the day distribution
Right: Pedestrian accidents at other areas of the road network - Time of the day distribution
Data source: FEDRO, 2016

4.2 Spatial Distribution

Using the method described in the Swiss Rule, entitled SNR 641724 [28], blackspots were identified. Within the framework of this project, the resulting accident clusters in the first district were studied. Precisely, it was examined whether there are blackspots at pedestrian crossings, if pedestrian accidents are dominant in these accident clusters, as well as the light and visibility conditions of the accidents consisting the aforementioned clusters.

4.2.1 Blackspots dominated by pedestrian accidents

Some blackspots are located in the central part of the city. For each of the 22 accidents clusters that are spotted in the district 1 the dominant accident type was determined and no blackspots having a percentage higher than 50% of pedestrian accidents were identified. Despite that fact, there is at least one blackspot with a percentage of 50% of pedestrian accidents, consisting of three pedestrian accidents (one slight, one severe, one fatal), a frontal collision (slight) and two accidents classified as other type (one slight, one severe). This blackspot is not close to a pedestrian crossing and there is no signal control (*Figure 4.9*). The absence of such infrastructure could be the reason of this blackspot's existence.

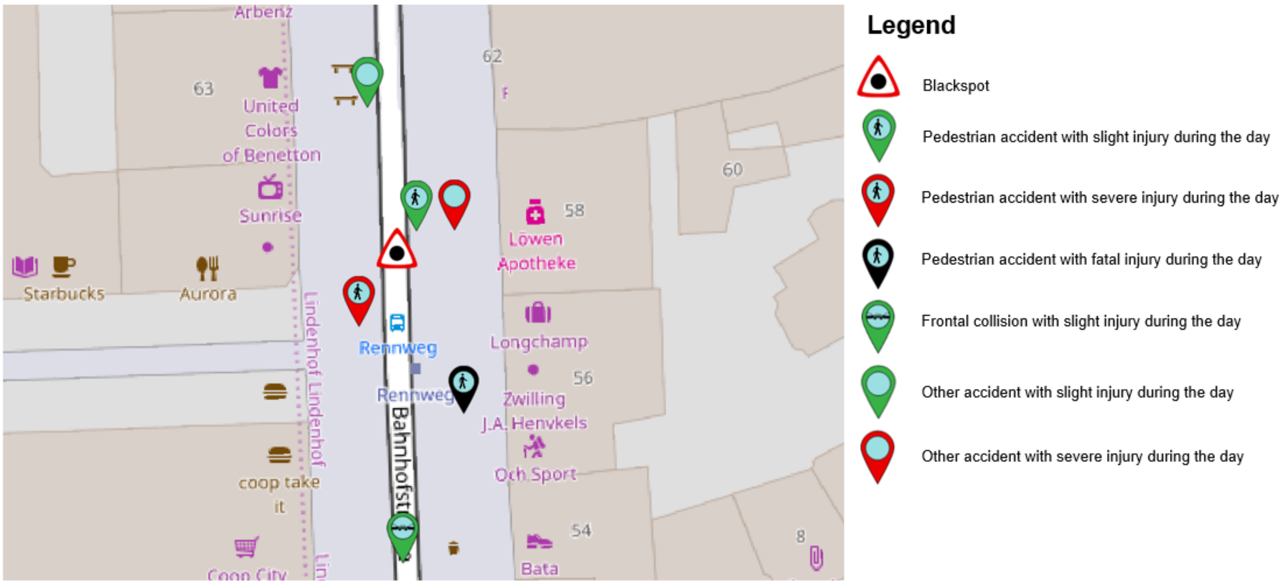


Figure 4.9: Blackspot close-up | Zurich, District 1
Data source: FEDRO, 2016 | Basemap: OpenStreetMap

4.2.2 Blackspots on pedestrian crossings

Among the accidents clusters located in the district under study, there are 19 which have a pedestrian crossing in a distance smaller than 25m (*Figure 4.10*).

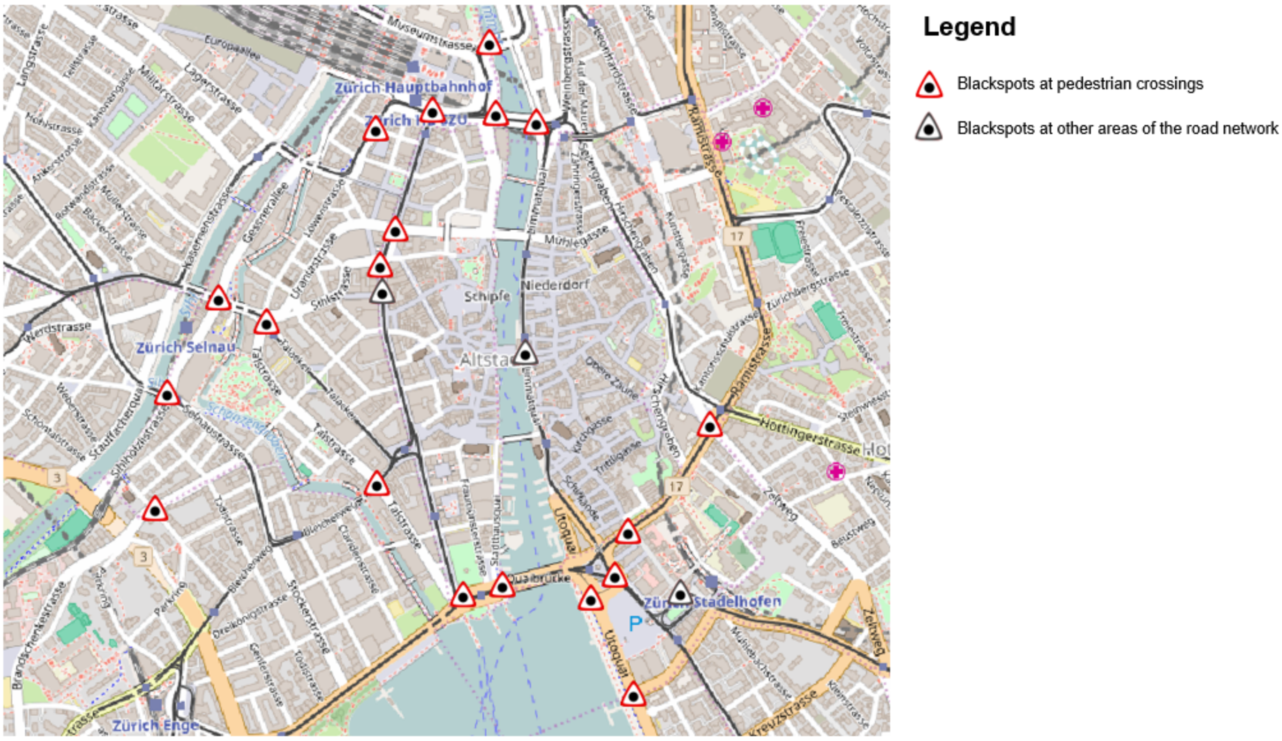


Figure 4.10: Pedestrian accidents in a distance smaller than 25m from pedestrian crossings | Zurich, District 1
Data source: FEDRO, 2016 | Basemap: OpenStreetMap

Since none of these blackspots is characterised by a high concentration of pedestrian accidents, the question that arises is whether the aforesaid blackspots emerge from the insufficiency of pedestrian crossings or they are related to the intersection, in the vicinity of the pedestrian crossing. It is observed that all pedestrian crossings which lie in the influence area of blackspots in the district 1 are close to intersections and that the majority of these intersections are signal controlled. Specifically, only two out of the accident clusters that include pedestrian accidents at pedestrian crossings are not located at a signalised intersection (*Figure 4.11*, *Figure 4.12*).

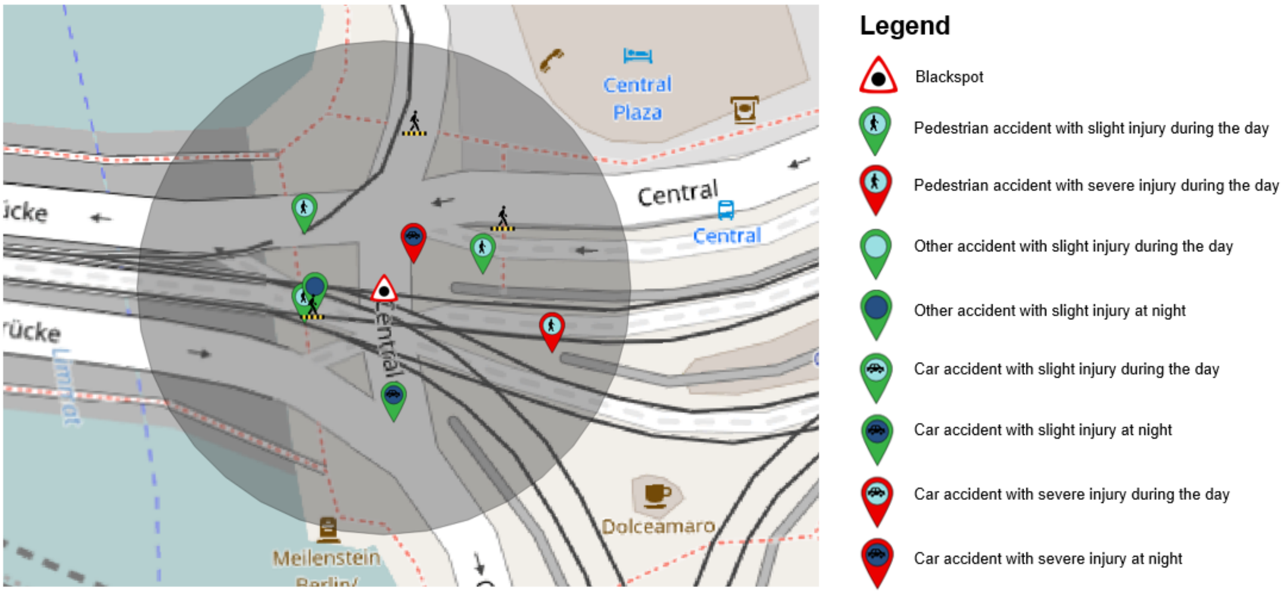


Figure 4.11: Accident cluster at non signalised intersection (I) | Zurich, District 1
Data source: FEDRO, 2016 | Basemap: OpenStreetMap

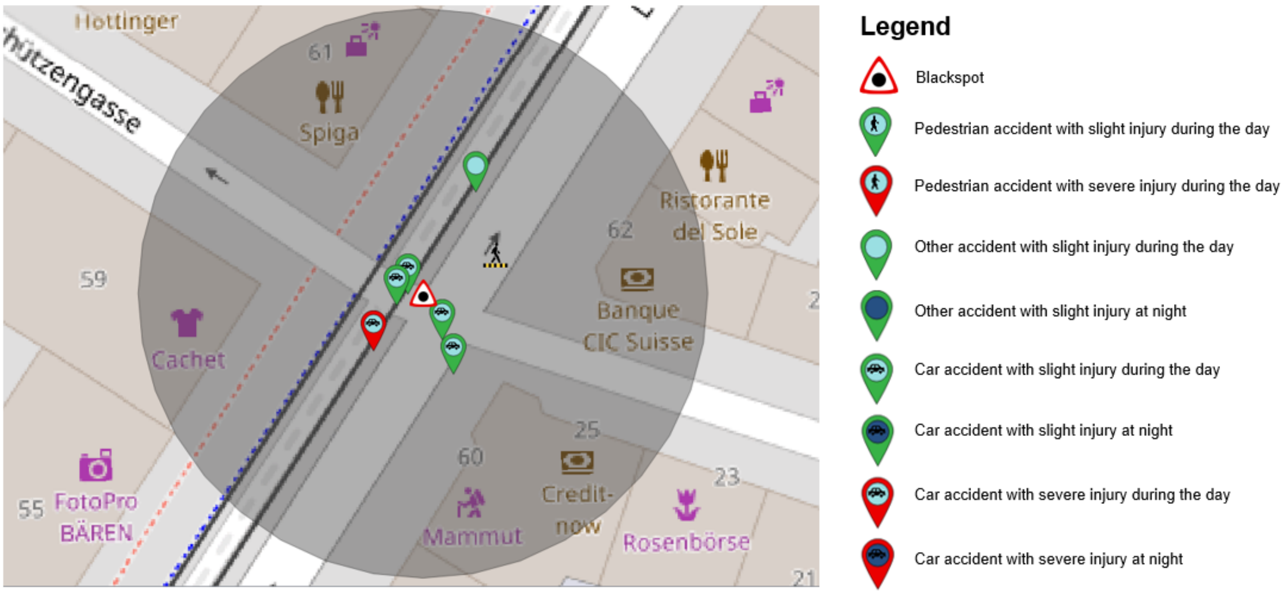


Figure 4.12: Accident cluster at non signalised intersection (II) | Zurich, District 1
Data source: FEDRO, 2016 | Basemap: OpenStreetMap

4.2.3 Blackspots & Light conditions

Concerning light conditions, for each accident cluster the most frequent light conditions were determined and it turned out that there are no blackspots with a high concentration of night accidents in the first district of Zurich.

4.2.4 Blackspots & Visibility conditions

At the current stage of the project the visibility analysis is not complete. However, it has already been assessed whether the minimum visibility distance is respected for the yellow stripes. It is noted that in the present analysis the distance thresholds are only based on the speed of the road and that the curvature is not considered due to time constraints. According to the analysis, 70 out of 108 non-signalised pedestrian crossings in district 1 where found to be insufficient. Among these crosswalks, there are only four which are close to blackspots. Three of these are included in *Figure 4.11* and *Figure 4.12*, while the fourth is presented below (*Figure 4.13*)). At this point it noted that the last-mentioned pedestrian crossing though seems not to be related to the accidents that are recorded in the area.

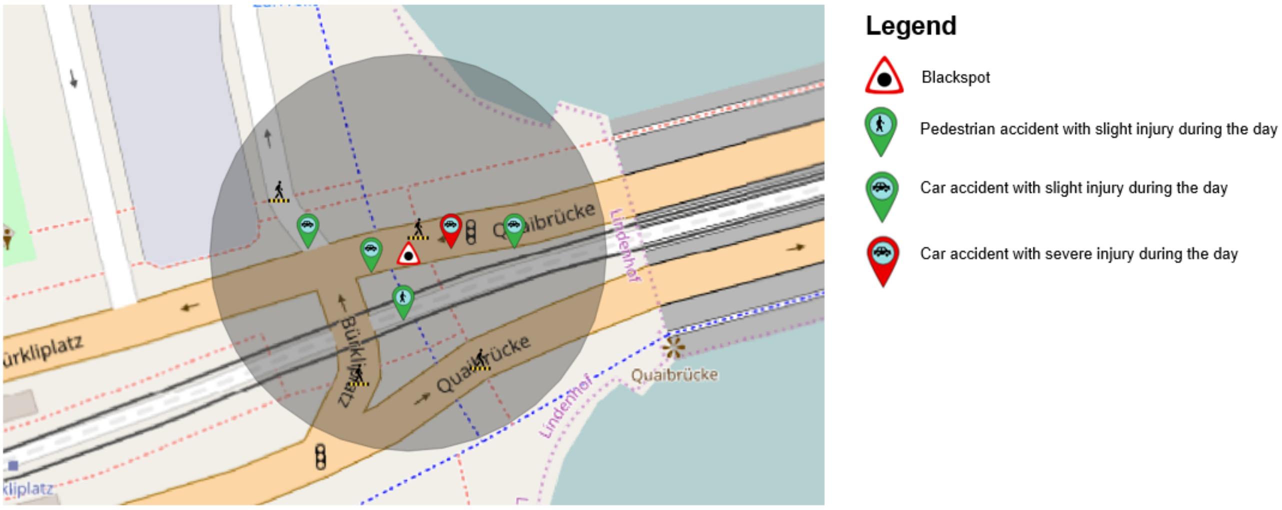


Figure 4.13: Non signal controlled pedestrian crossing with visibility issues in the area of influence of a blackspot | Zurich, District 1
Data source: FEDRO, 2016 | Basemap: OpenStreetMap

5 Detecting Problematic Pedestrian Crossings

The present chapter treats of the assessment of pedestrian crossings. In the paragraphs below the appraisal method and its implementation are given in detail. What's more, the results of the assessment are presented.

5.1 Method

The assessment of pedestrian crossings is based on the comparison of their geometric design, the surroundings and the traffic conditions with a standard that is considered as the ideal pedestrian crossing. The main definition of such a standard is given in the SN 640241. Thus, a toolbox has been developed for the implementation of the rules described in the norm.

5.2 Toolbox

The development of the toolbox was done in ArcPy, as Python is pretty powerful for data analysis and ArcPy simplifies the processes related to geodata. Furthermore, considering the popularity of ArcMap, a toolbox functioning in this environment seems to be a good choice. Moreover, the possibility of uploading the tool to an ArcGIS Server and then call it from a web map application takes the development to whole new level.

In the context of this project the toolbox has been created and it can be used for offline analysis in ArcMap. In the future it is aimed to be embedded in a web map application. Regarding the structure of the toolbox, it consists of five tools, each including a set of rules from the norm (*Figure 5.1*). More specifically, there is the equipment tool that examines whether the traffic signs and the artificial lighting are sufficient. Furthermore, there is the geometry tool that checks the dimensions of the waiting rooms, as well as their total number for each crossing. Moreover, the location tool treats the distance of the pedestrian crossings from other pedestrian crossings, traffic lights and public transport stops. In addition, the traffic conditions tool determines whether the crossing is signal controlled and if the speed and also the pedestrian and vehicular volume allow the existence of the pedestrian crossing. Finally, the visibility tool examines the visibility and the visibleness of the pedestrian crossings. It is noted that these tools are designed based on the data collected by the city of Zurich, which the team was provided with. Besides, it is underlined that they are not fully functional either due to lack of specific information or because they are still under development.

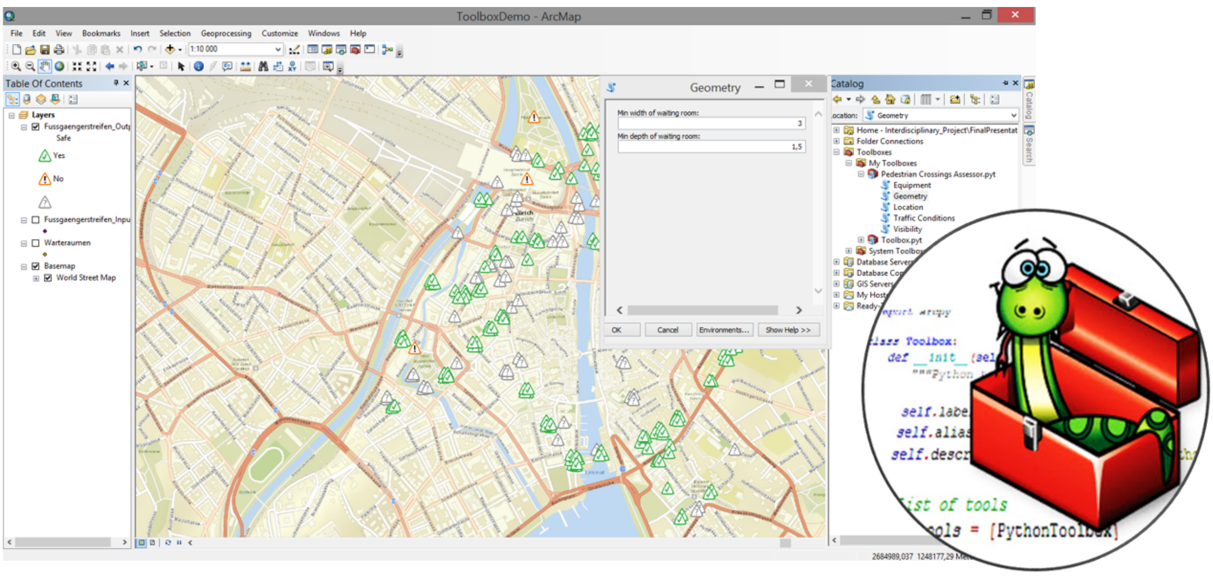


Figure 5.1: Snapshot of the toolbox
Data Source: City of Zurich (DAV), ESRI etc, 3.bp.blogspot.com

5.3 Results

In this section, the results of the assessment using the finished parts of the assessor are presented.

5.3.1 Equipment's sufficiency

This tool is still under development and no results are yet available.

5.3.2 Geometrical appraisal

This tool takes into consideration the dimensions of the waiting rooms, however it does not yet examine whether the existence of refuge islands is necessary and which their number should be according to the norm. Based on the analysis, 8 out of 70 non-signalised pedestrian crossings were found to have insufficient waiting rooms in terms of dimensions. It is noted that signalised pedestrian crossings are not examined since the new norm does not treat them. The image below shows the location of the deviating crosswalks in the city.

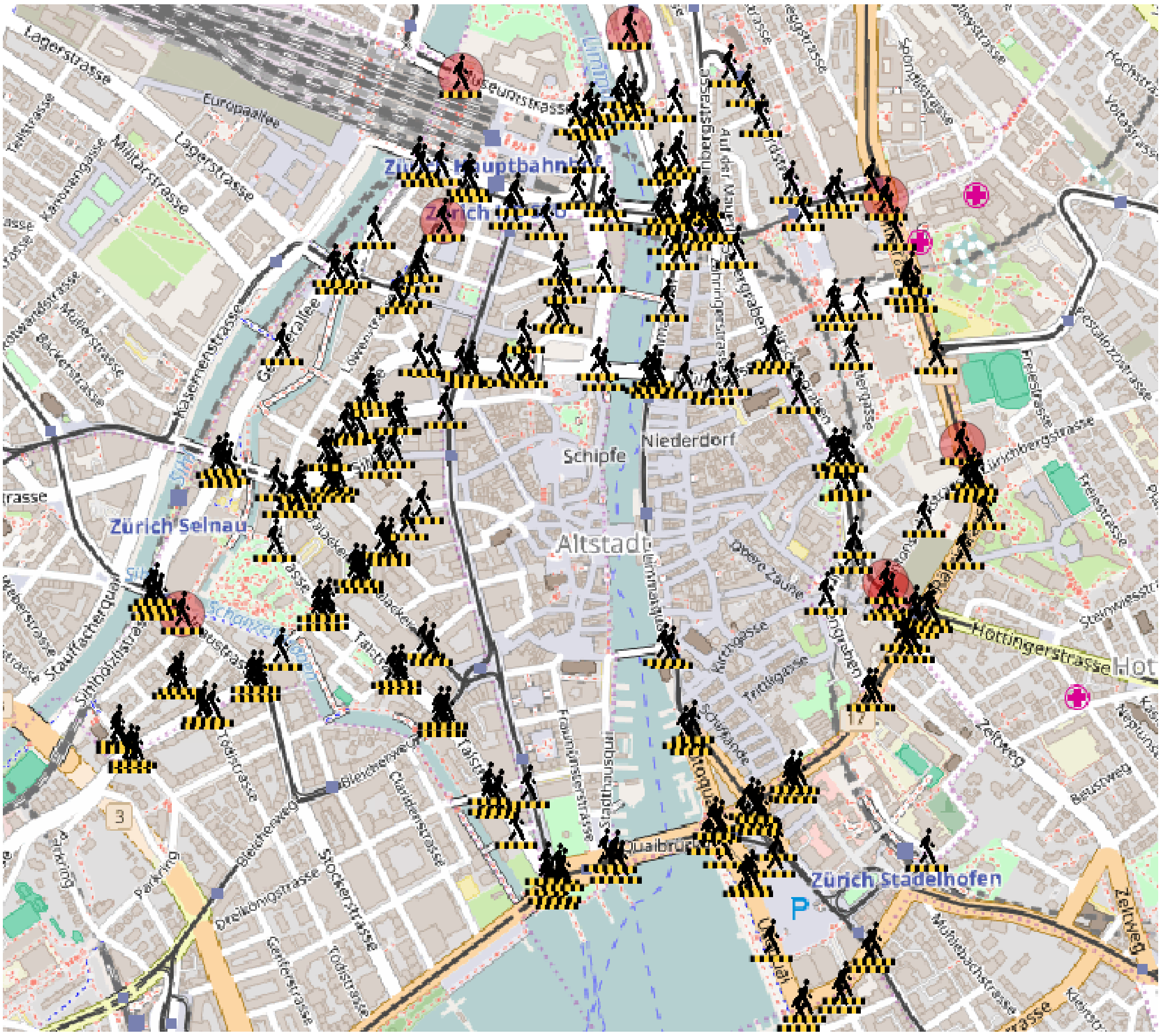


Figure 5.2: The pedestrian crossings with insufficient waiting rooms are highlighted with a red circle
Data Source: City of Zurich (DAV), FEDRO | Basemap: OpenStreetMap

It is also emphasised that only one of these pedestrian crossings is close to an accident cluster, which actually does not include any pedestrian accidents. It is the one shown in *Figure 4.12*. In addition, just two of these crosswalks are located close to individual road accidents, between which only one involves a pedestrian. Hence, the waiting room width parameter, which is the reason of the deviation from the ideal pedestrian crossing for the aforementioned crossings, might not affect pedestrian safety.

5.3.3 Location assessment

The location tool is also under construction. What is already completed is the examination process for the distance of a pedestrian crossing from the closest pedestrian crossings and traffic lights. The analysis showed that there was not such a problem in the first district of Zurich.

5.3.4 Traffic conditions' assessment

As far as traffic conditions are concerned, the respective tool checks whether the speed of the road and the AADT allow the existence of the pedestrian crossing. In the current state, the parameter of the pedestrian traffic is disabled due to lack of data. As for the results, no pedestrian crossing is classified as insufficient due to these parameters.

5.3.5 Visibility sufficiency

Regarding visibility, it was mentioned approximately 65% of the non-signal controlled crossings of the district, have visibility issues (*Figure 5.3*). Furthermore, four of these problematic crosswalks lie on the zone of influence of blackspots while 43% of these deviating pedestrian crossings are close to individual accidents. Concerning the last-mentioned individual accidents 29% of them involved pedestrians. Thus, this parameter is considered to be of paramount importance for road safety.

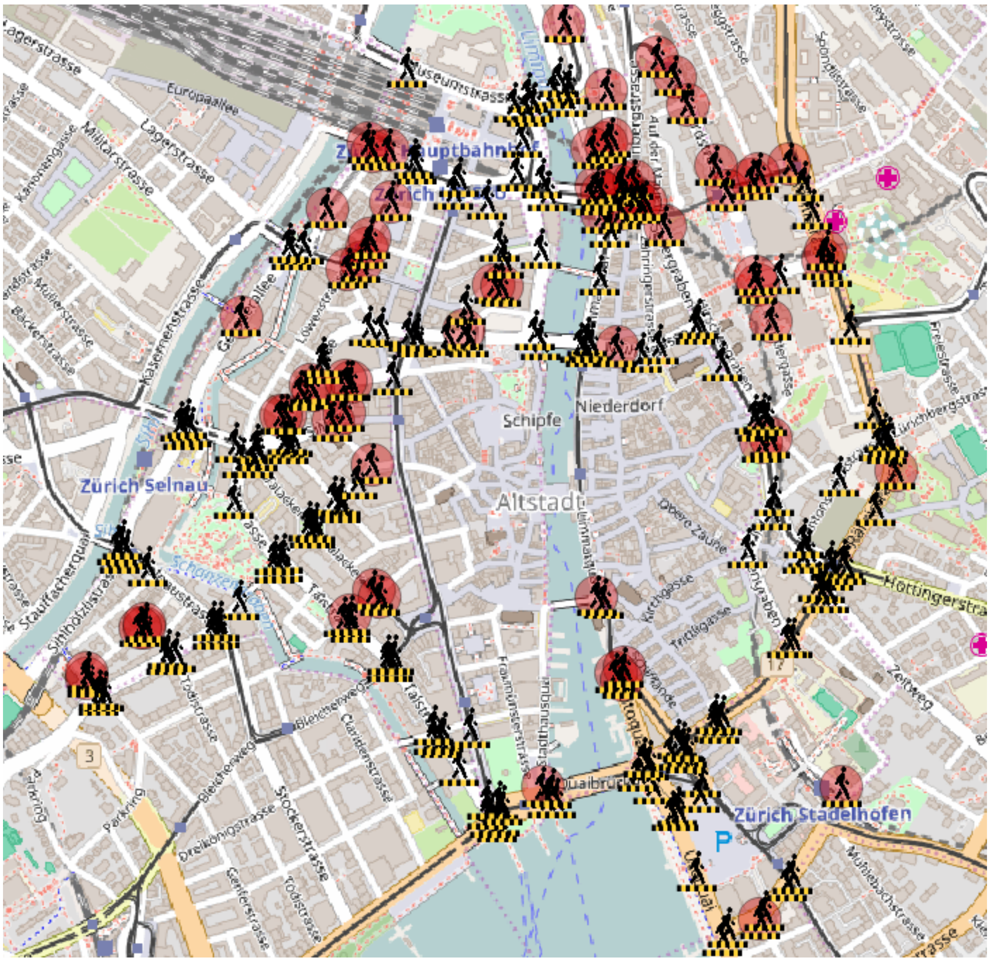


Figure 5.3: The pedestrian crossings with visibility issues are highlighted with a red circle
Data Source: City of Zurich (DAV), FEDRO | Basemap: OpenStreetMap

6 Putting the Problem on the Map

This chapter is dedicated to the web map application that was developed to showcase the results of the present study.

6.1 The Idea

Considering the effectiveness of maps as presentation, pattern identification and communication tools [29], their use in road traffic safety management becomes imperative. What's more, the development of a web map application, that not only depicts road traffic accidents but it also shows the dangerous points of the road network based on the analysis of both the accident data and the geometry of network elements, could serve as decision-making tool for road safety. Worldwide, a few road accident web maps exist and most of them just present the distribution of road accidents. Some of them offer additionally some statistics, while only two among them have integrated analysis tools. The last-mentioned applications, are developed by the University of Minnesota & the Claremont Graduate University and the University of California, Berkeley (UC Berkeley) respectively. The former is the SafeRoadMaps project, which provides data filtering, statistics, crash analysis tools and even a real-time safety tracker [30]. The latter, entitled TIMS offers data filtering, layer selection and a rank by intersection feature [31]. Snapshots of the above-mentioned advanced web map applications are presented in *Figure 6.1*.

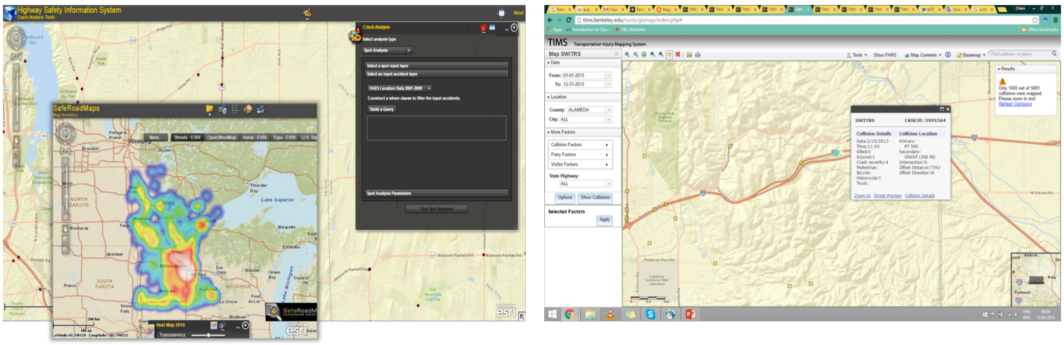


Figure 6.1: Left: Snapshot of the *SafeRoadMaps* project [30], [32]
Right: Snapshot of the *SRMTIMS* project [31]

Focusing on Switzerland, although there are two web map applications related to road safety in the federal territory, both of them perform only basic operations. The first just visualises the accidents distribution while the second[1] offers additionally data filtering and gives some statistics, but none of them provides any information about the safety level of the network. Snapshots of these applications are presented in *Figure 6.2*.

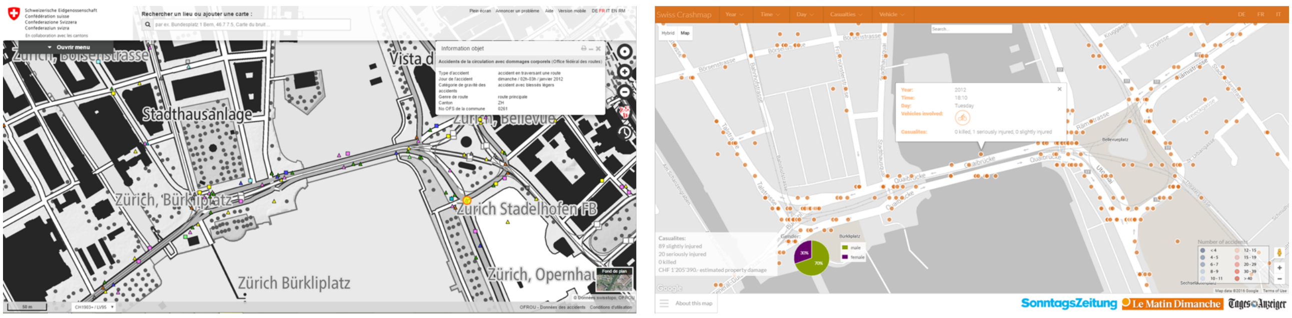


Figure 6.2: Left: Snapshot of Road Traffic Accident Map from the Portal of the Swiss Government [33]
Right: Snapshot of Road Traffic Accident Map from the collaborative project of three Swiss newspapers and a Research Centre [34]

[1] This application seems to be unavailable at the moment.

In order to fill the gap indicated above, a web map application was developed. The aim of the application is to showcase the results of this study and to present the safety conditions of Zurich's road network. In more detail, accident data and blackspots are put on the map together with pedestrian crossings and information about their condition. Other related data such as AADT and speed limits are included. The application offers widgets as for example, geocoding, measurement and buffer, and in the future a geoprocessing widget calling the toolbox described in the previous section will be added. This application could probably be addressed to road authorities as assisting tool and perhaps to the general public as information medium.

6.2 Implementation

In this section the main points related to the implementation of the web map application are presented, starting from the elaboration of the different layers of the map and continuing with more details concerning the programming part.

6.2.1 Basemap

Regarding the basemap, ESRI's *World Street Map* was edited and finally used. The disadvantage of this particular basemap though is that the highest available scale is the 1:1250. In spite of that, this map includes detailed layers related to the topic of the map.
Concerning the preference for the *World Street Map* over the *World Topographic Map* of ESRI, which reaches a scale of 1:100, it is based on the possibilities of customisation (*Figure 6.3*, *Figure 6.4*). It is emphasised that the topographic map is not editable, for there is not possibility to either modify the json style file or customise it in the online editor for ESRI basemaps, whereas this option is available for the street map. At this point, it is underlined that the modification process was necessary for the basemap, in order to remove redundant information as well as to conceal layers that were provided in a more accurate version from the city of Zurich. Such is for instance the case of the tree layer.

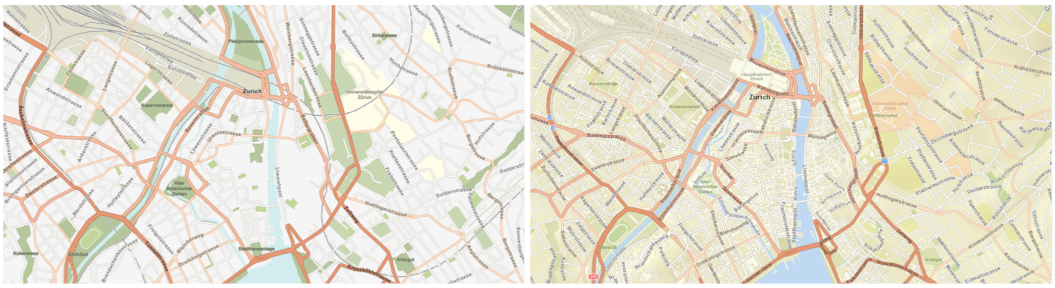


Figure 6.3: Left: Snapshot of the customised basemap (I)
Right: Snapshot of the original *ESRI's World Street Map* (I)
Data Source: ESRI, DeLorme, HERE, Garmin, INCREMENT P, NGA, USGS

Figure 6.4: Left: Snapshot of the customised basemap (II)
Right: Snapshot of the original *ESRI's World Street Map* (II)
Data Source: ESRI, Delorme, HERE, Garmin, INCREMENT P, NGA, USGS

6.2.2 Thematic layers

As for the thematic layers, relevant datasets were added on the map, some of them present basic information on the topic while some other supplement the map with additional information, mostly suitable for all users and partly addressed to specialists, to help them draw further conclusions. The datasets were provided by the Department of Transport (DAV) of the city of Zurich, by the OpenData Portal of the city of Zurich, the Federal Roads Office (FEDRO) and the Institute for Transport Planning and Systems (IVT) of ETH Zurich.
It is noted that all datasets were processed before being added on the map. The standard operations included clip to the area of interest and transformation of coordinate system.

6.2.3 Technical details

As far as the technical details are concerned there were many challenges during the development of the application.

Code Contribution

Modifying and adding code to the template of ESRI's Web AppBuilder is tricky not only due to the complex structure of the application file but also because the Web AppBuilder is founded on the ArcGIS API for JavaScript and the Dojo Toolkit.
What the author mostly worked on was the customisation of the added widgets. To do, it was necessary to understand their structure which looks like in *Figure 6.5*.

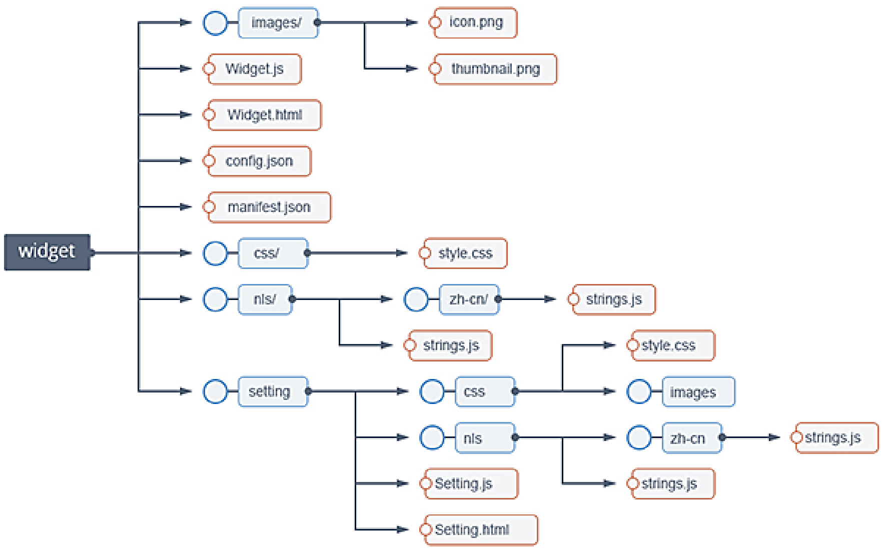


Figure 6.5: The widget's structure [35]

Implementing the Zoom Based Appearence

The thematic layers are published as feature services in ArcGIS Online. The map was also composed in ArcGIS Online and it was observed that there was no way to define zoom based symbolisation. Therefore each layer was added multiple times on the map, each time with a marker of different size, using the visibility range feature in order to give the zoom based effect. The map is available for scales between 1:40000 and 1:1250 and concerning the symbolisation, four levels were defined.
The fact that each layer is added many times means that each layer also appears multiple times in the layer list. This problem was solved programmatically. However, another problem appeared, that of selecting and deselecting a thematic entity at all its zoom levels. To overcome this issue an empty layer was added for each thematic entity. The empty layers were the only layers appearing in the layer list and a piece of code was also written in order to use them to activate and deactivate all the layers of the thematic entity.

6.3 The Final Product

In this section details of the final product are pointed out, including the general layout, the loading page, the zoom based appearance, the responsiveness and the accessibility of the web map application.

6.3.1 Layout

As for the general layout the figure below speaks for itself, presenting the main elements of the application.

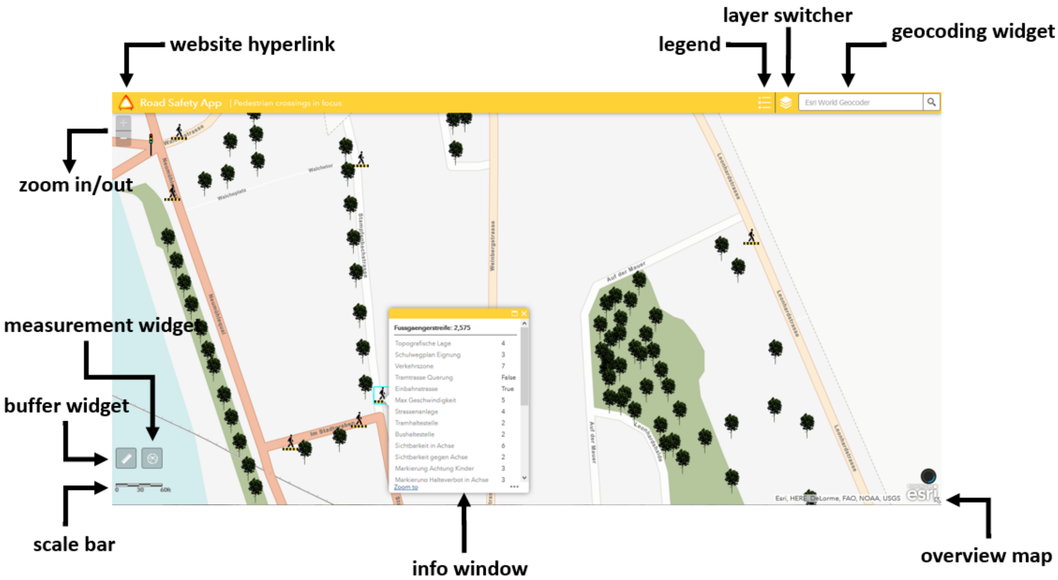


Figure 6.6: Web map application
Data Source: DAV, FEDRO, IVT, OpenData Zürich, ESRI etc

6.3.2 Loading screen

While the application is being loaded the loading screen appears. In this page, the mascot of the application shows up with yellow bars appearing on by one as times goes by, looking like the stripes of pedestrian crossings (*Figure 6.7*).

Figure 6.7: Loading screen [36]

6.3.3 Zoom based appearance

As mentioned in the technical details section the appearance of the map is zoom based. The markers and the general overview at different zoom levels are shown in the following figure (*Figure 6.8*).

Figure 6.8: Zoom based appearence
Data Source: DAV, FEDRO, IVT, OpenData Zürich, ESRI etc

6.3.4 Responsiveness

The templates included in the Web AppBuilder for ArcGIS are responsive and this was one of the reasons of developing the application in this environment. Hence, the final product is responsive, as also shown in the figure below (*Figure 6.9*)

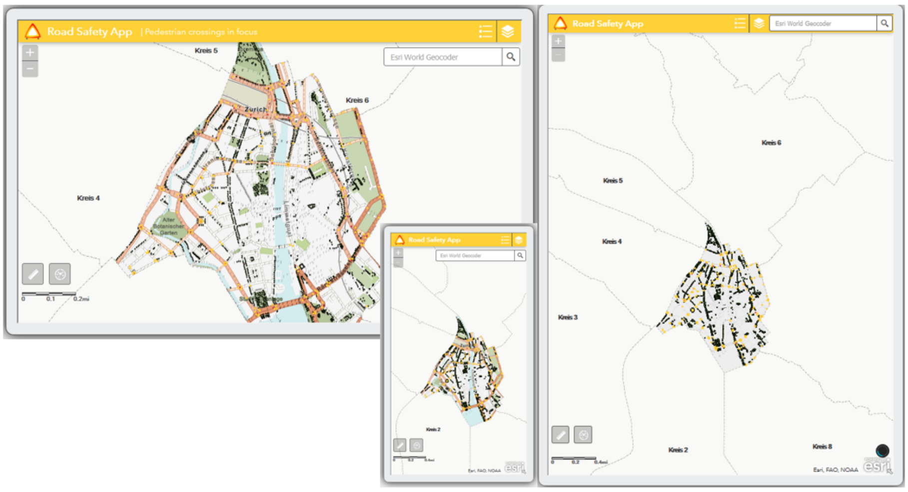


Figure 6.9: Responsive design
Data Source: DAV, FEDRO, IVT, OpenData Zürich, ESRI etc

6.3.5 Accessibility

The final product is hosted in ArcGIS Online, however it is not yet shared due to privacy issues that should be discussed before publishing the application. To be more precise, permission should be asked before opening to public a product that presents sensitive data.

7 Informing the Public

It is not only the infrastructure that matters, it is also the road users themselves and information is a way to make road users more prudent. Besides, most people wouldn't expect accidents to happen on pedestrian crossings. Towards this aim, a website was created. Details about the idea of the information webpage, its implementation and the final product follow.

7.1 The Idea

The idea was to make a website to serve as information medium for the general public. The design aims to showcase simple and concise notes, supplemented with imagery showing that, road accidents still occur, even on pedestrian crossings.
Since the website is addressed mainly to the inhabitants of Zurich the website is available in both English and German.

7.2 Implementation

The website is built on the main pillars of web development, namely HTML, CSS and JavaScript, the JQuery library and the Bootstrap framework.

7.3 The Final Product

The present section is a thorough presentation of the final product. Details about the design and the accessibility of the website are also given.

7.3.1 Layout

The website is divided into eight sections. The first one presents road accidents, mostly with cyclists involvement, from the period 1920-1947. Then the second section presents recent crashes (2008-2016), some of which involve cyclists or pedestrians. The third section, aims to raise the awareness for the future while the fourth, shows that the efforts should be concentrated on pedestrian crossings. Next, the fifth section includes some details and some statistics related to the addressed problem and it links the website to the web map application (*Figure 7.1*). Afterwards, in the sixth section some details about the team of the project are given, followed by a contact form in the seventh section. Finally, the eighth section gives credits for all elements that come from external sources (*Figure 7.2*, *Figure 7.3*).

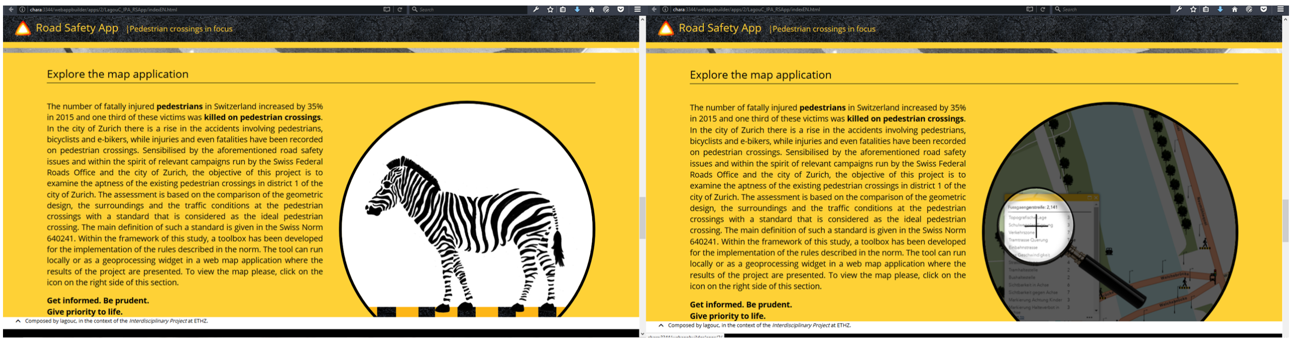


Figure 7.1: By clicking the icon the web map application opens

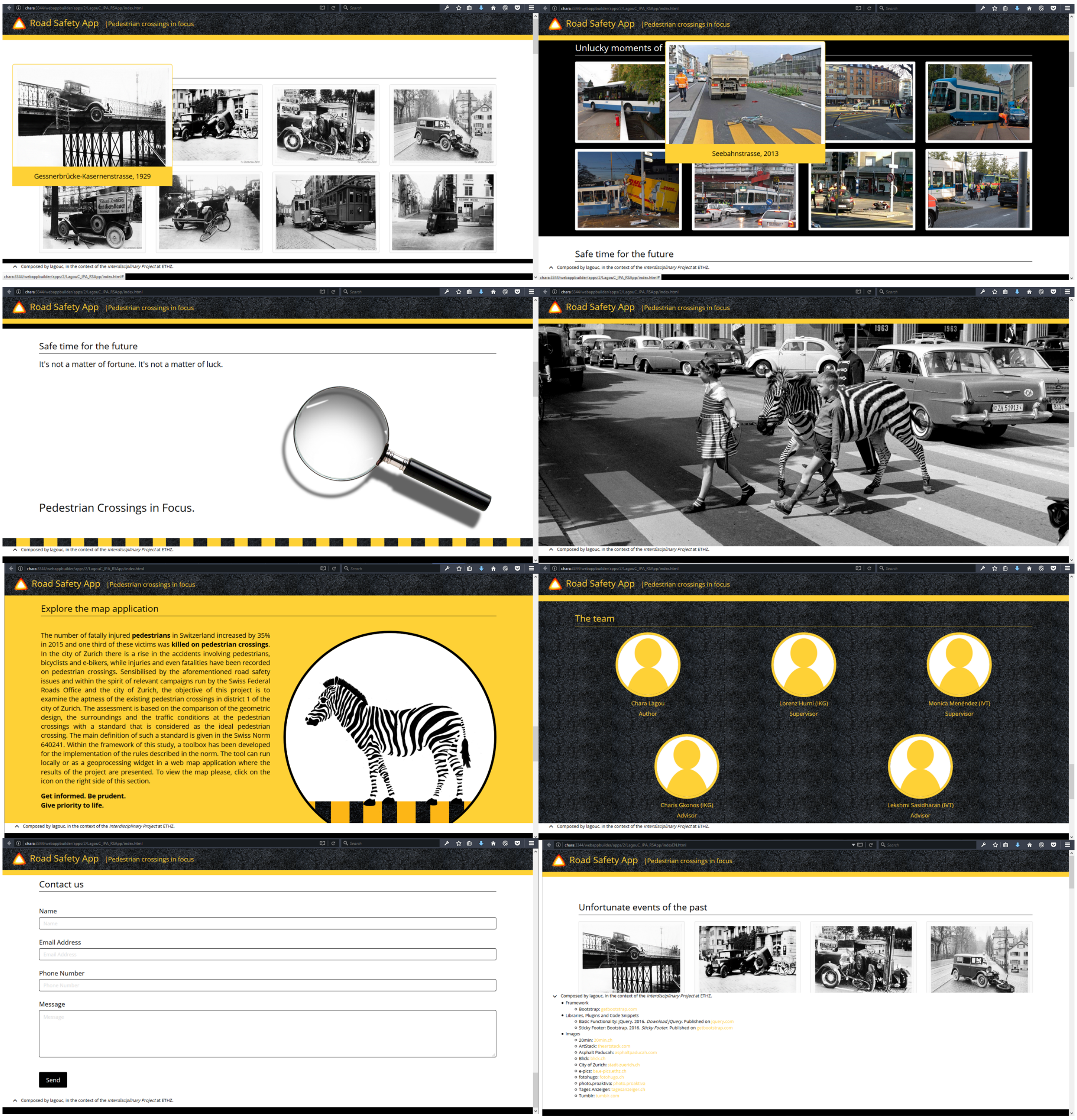


Figure 7.2: English Website

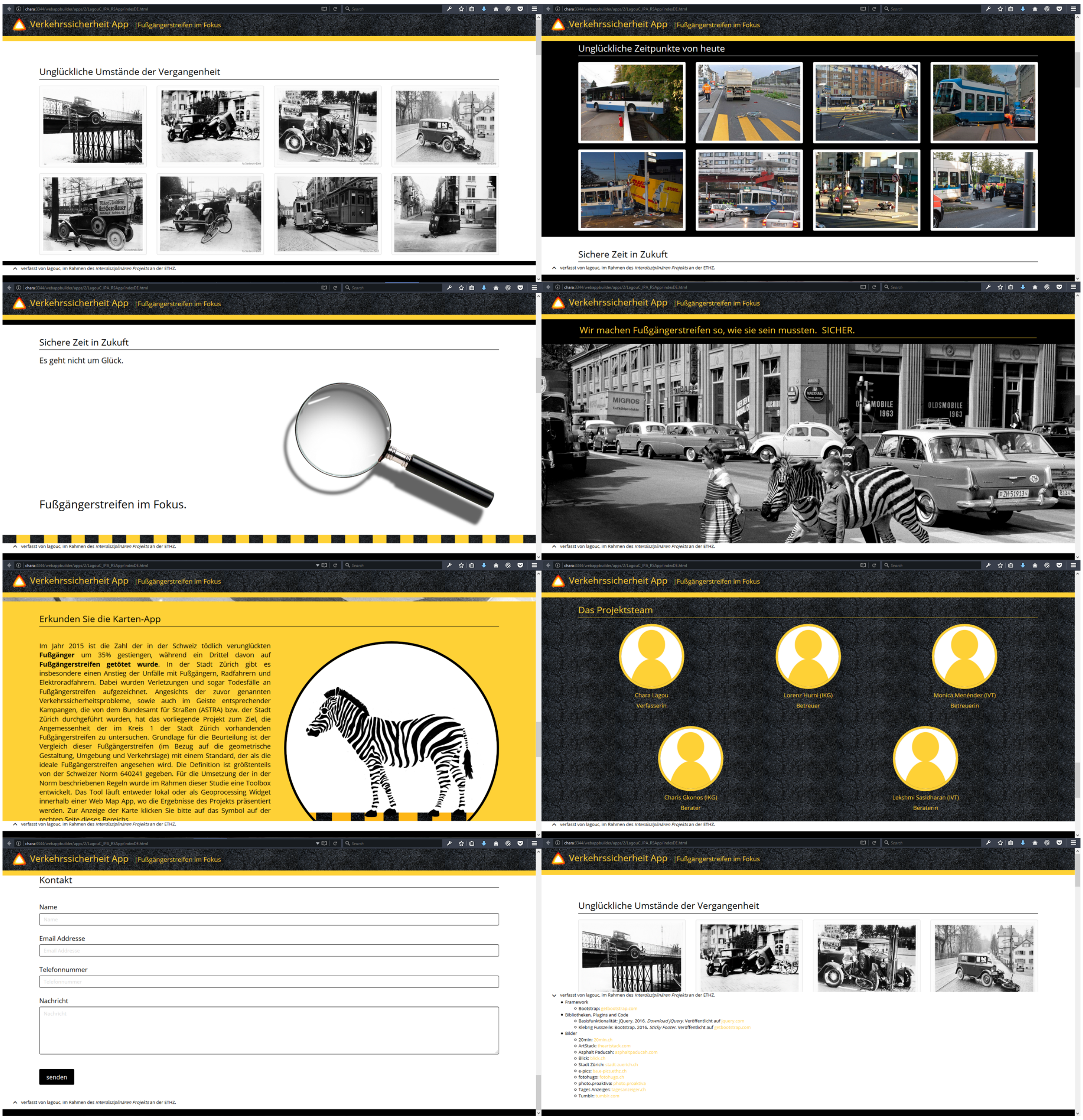


Figure 7.3: German Website

7.3.2 Responsiveness

Using the tools of the Bootstrap framework the website was designed to be more or less responsive. There are still some issues that have to be solved for smartphone screens, however the webpage looks good on either landscape or portrait desktop screen, on laptops and tablets (*Figure 7.4*)

Figure 7.4: Responsive design
Data Source: City of Zurich

7.3.3 Accessibility

The website is at the moment hosted in ArcGIS Online, in the folder of the web map application. Thus, its not yet open for the public. As soon as the application is published the website will become available too.

8 Conclusions & Future Work

The phrase *Records of pedestrian fatalities on pedestrian crossings* sounds like an oxymoron, however, facts claim that globally more than 250000 pedestrians pass away on pedestrian dedicated facilities annually. The problem exists in Switzerland as well, where one third of the pedestrian victims of 2015 was killed on pedestrian crossings. In the city of Zurich, a rise in the accidents involving pedestrians, bicyclists and e-bikers is noted, while injuries and even fatalities have been recorded on pedestrian crossings. Sensibilised by the aforementioned road safety issues and within the spirit of relevant campaigns run by the Swiss Federal Roads Office and the city of Zurich, the objective of the present interdisciplinary project is to examine the aptness of the existing pedestrian crossings in district 1 of the city of Zurich. The appraisal is based on the comparison of the geometric design, the surroundings and the traffic conditions at the pedestrian crossings with a standard that is considered as the ideal pedestrian crossing. The main definition of such a standard is given in the Swiss Norm 640241. In the context of this study, a toolbox has been developed for the implementation of the rules described in the norm. Furthermore, a website was created, as well as a web map application where the results of the project are presented. The final product could probably serve as an assisting tool for road authorities and perhaps as information medium for the general public.
As far as the results of the research are concerned, the following conclusions are drawn for the case of Zurich's district 1:

- It is likely that pedestrian accidents which happen at pedestrian crossings and pedestrian accidents which occur at other parts of the road network constitute two separate accident categories. This statement results from the difference in their temporal patterns, for the former is characterised by a regularity whereas the latter is not. More specifically, the day distribution of pedestrian accidents that happened at pedestrian crossings reminds of the traffic volume pattern, and it might be connected with scheduled trips and perhaps regular road users. Furthermore, concerning the time distribution, these accidents are observed mostly between 06:00 and 00:00, which are the high activity hours for modern humans.
- Taking into consideration that most of the blackspots, which have a pedestrian crossing in their area of influence, are not dominated by pedestrian accidents, and that most of the crosswalks included in such zones are close to intersections, at most cases signalised, it becomes clear that it is probably the intersection and not the pedestrian crossing itself that causes the road accidents in the area.
- Non intense lighting problems are recorded in the same area as there are no blackspots dominated by night accidents.
- In the center of the city the traffic condition and location criteria are respected.
- The width of the waiting rooms might not have an impact on pedestrian safety as only one of the deviating pedestrian crossings is close to an individual pedestrian accident, which could be a matter of chance. Besides, the rest of the insufficient crosswalks are located in the vicinity of another individual accident and a blackspot, which had no pedestrian injuries.
- The fact that 65% of the non-signalised pedestrian crossings do not fulfil the visibility requirements and that 43% of these crosswalks are in the vicinity of blackspots and individual clusters which include pedestrian accidents, is an argument for the idea that visibility is of great importance for pedestrian safety.

Finally, some of the future plans are presented. First of all, the toolbox will be enriched with more functionality and the final version will be uploaded on an ArcGIS Server. What's more, the analysis will soon expand to the whole city. As for the web-based communication media, there is room for improvement for both the web map application and the website and many additions are planned, such as the geoprocessing widget that will make the toolbox hosted on the server available for the users of the web map application.

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